THE EVOLUTION OF FIRE INVESTIGATION, 1977-2011

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INTRODUCTION

The first step in investigating an alleged arson fire is to make certain that the fire was, in fact, intentionally set. Except in the most obvious cases, this step requires expert assistance from a knowledgeable fire investigator. This article will describe the changes that have impacted the fire investigation profession over the last three decades. Although the change has been gradual and at times maddeningly slow, the pace of change has stepped up even as our knowledge of fire behavior makes us less certain about the accuracy of fire origin and cause determinations. Criminal justice professionals should be aware of the changes in the science, to enable them to decide whether to go forward with the prosecution, mount a defense, or challenge evidence based on its reliability or lack thereof.

The old expression "the more you learn, the less you know" is truer in fire investigation than in just about any other forensic science discipline. If one looks back to the mid-1970s and compares the state-of-the-art in fire investigation then with the state-of-the-art today, there are many significant differences. The 80s and 90s were a time of very gradual change, as it became clear that many of the "rules of thumb" for fire investigation turned out to be based on anecdotal evidence at best and witchcraft at worst.

In 1977, the Law Enforcement Assistance Administration (LEAA) reported the results of a survey of fire investigators in a publication entitled *Arson And Arson Investigation: Survey And Assessment*. This report contained a compilation of the "indicators" of incendiary activity used by fire investigators at the time. The authors of the survey warned that **none of the indicators had been scientifically validated** and recommended a series of carefully conducted experiments to learn whether these indicators were (or were not) valid. Three years later, the National

Bureau of Standards (NBS-now called the National Institute of Standards and Technology, or NIST) produced a document called *Fire Investigation Handbook*, which repeated all of the indicators, and gave them the imprimatur of the most credible science and engineering institution on the planet. Unfortunately, **none** of the scientific experiments required to validate these indicators had been conducted. The NBS simply took the word of two instructors from the National Fire Academy, which resulted in numerous textbooks being written with the mythology of arson investigation permanently embedded. It would take more than two decades to undo the damage.

In 1985, the Standards Council of the National Fire Protection Association (NFPA) became concerned with the quality of the work product of fire investigators, and commissioned the Technical Committee on Fire Investigations. The Technical Committee was asked to draft a guideline for fire investigators, and that task took seven years. The first edition of NFPA 921, *Guide for Fire and Explosion Investigations*, was published in 1992. To state that NFPA 921 was not immediately embraced by the fire investigation profession would be a serious understatement. In fact, the howls of protest from fire investigation "professionals" were deafening. If what was printed in "that document" were actually true, it meant that hundreds or thousands of accidental fires had been wrongly determined to be incendiary fires, i.e., intentionally set. No investigator wanted to admit to the unspeakable possibility that he had caused an innocent person to be wrongly convicted, or a family to be denied their life savings. The profession was in denial.

The first serious challenge to the "old school" of fire investigators came in 1996 in *Michigan Millers Mutual Insurance Company v. Janelle R. Benfield*, (*Millers Mutual Insurance Company v. Janelle R. Benfield*, 140 F.3d 915 (11th Cir. 1998), available at http://caselaw.findlaw.com/us-11th-circuit/1396573.html.) in which a fire investigator who failed to properly document his observations was excluded from testifying. In the appeal of that exclusion, the International Association of Arson Investigators (IAAI) filed an *amicus curiae* brief, in which they contended that fire investigators should not be held to a strict reliability inquiry because fire investigation was "less scientific" than the kind of scientific testing discussed in the Daubert decision of 1993. Eventually though, there were enough court rulings, including the unanimous Supreme Court decision in *Kumho Tire v. Carmichael,* to persuade the majority of fire investigators that it was necessary to accept the scientific method recommended by NFPA 921.

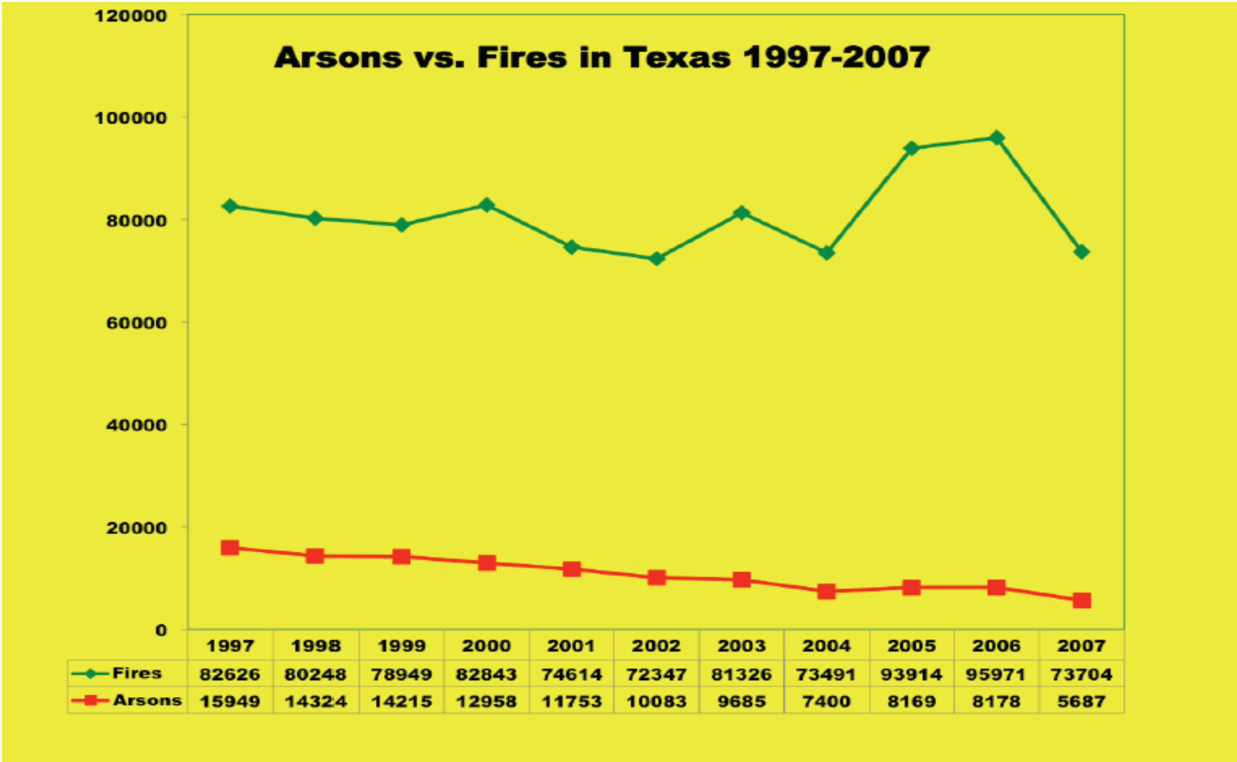
It is difficult to state exactly when NFPA 921 became "generally accepted by the relevant scientific community," but 2000 was an important turning point. That year the United States Department of Justice released a research report entitled *Fire And Arson Scene Evidence: A Guide For Public Safety Personnel*, which identified NFPA 921 as a "benchmark for the training and expertise of everyone who purports to be an expert in the origin and cause determination of fires." That same year, the IAAI for the first time endorsed the adoption of the new edition of NFPA 921.

Currently, most fire investigators will acknowledge that the scientific method is the only valid analytical process by which one can reach reliable and accurate opinions and conclusions regarding the origin and him cause of a fire. There are some, however, who neither understand nor follow the scientific method.

A MORE CAUTIOUS APPROACH

One thing that NFPA 921 has accomplished is to make it easier to distinguish between credible investigative results and those based on hunches and feelings or discredited mythology. The *Guide* provides the investigator with the tools to do his or her job, but demands that conclusions be justified with data, sound science, and clear reasoning. This is a good result. Based on my 35 years of studying fires, including more than 2,000 actual fire scene inspections (about 800 of which I determined to be arson) I learned two important things: most fires are accidents, and most arson fires are obvious. Surely there are exceptions, but if a fire investigator over and over again reports an incendiary determination that seems difficult to understand, chances are this investigator needs to find another line of work in which the consequences of error are not as serious.

Some recent high-profile criminal arson cases from Texas have attracted the attention of the public and the media and have resulted in some interesting studies regarding the prevalence of arson in the United States. Dave Mann of the *Texas Observer* became interested in the study of errors in fire investigation as a result of the cases of Ernest Ray Willis (who was exonerated after 17 years on death row) and Cameron Todd Willingham (who was executed after 12). He published a study that included a count of total fires in Texas versus the number of fires determined to be arson. (See Figure 1.) Those results showed a more than 60% drop in the number of fires determined to be arson between 1997 and 2007. (Dave Mann, "Fire and Innocence," *Texas Observer*, November 27, 2009.) After reviewing the data



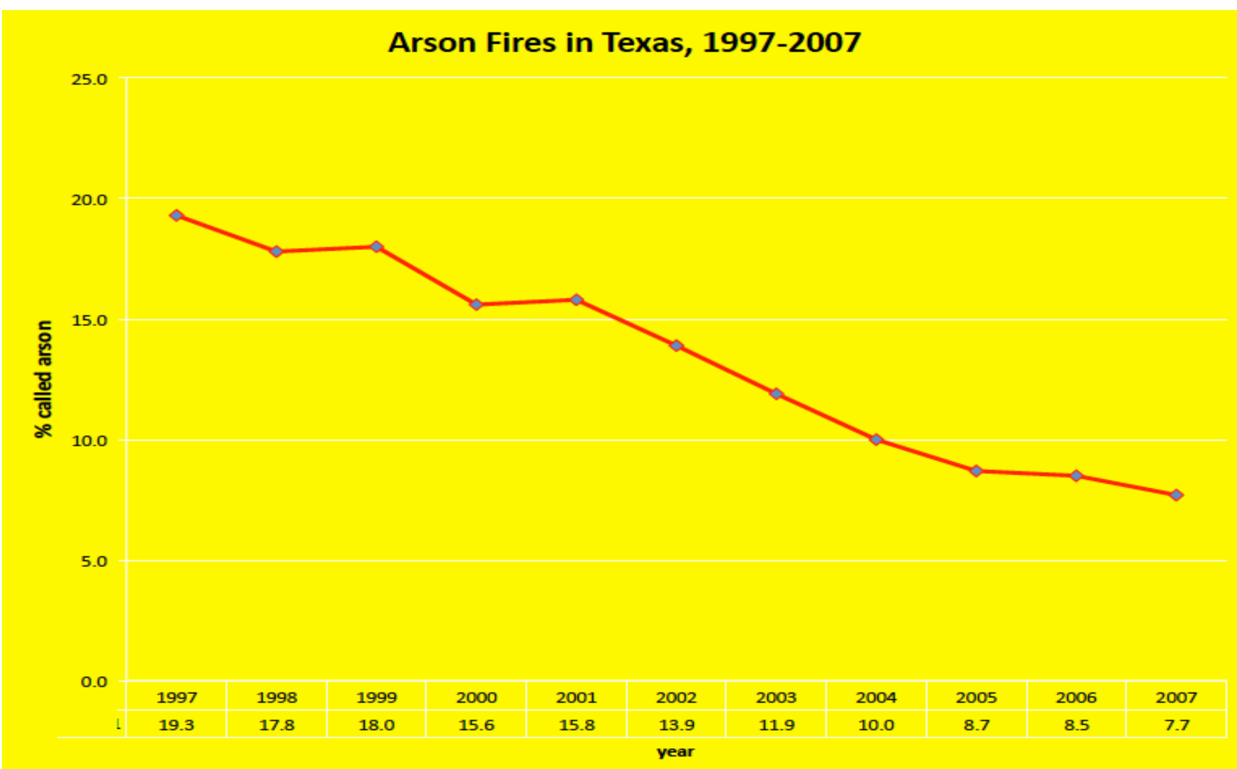
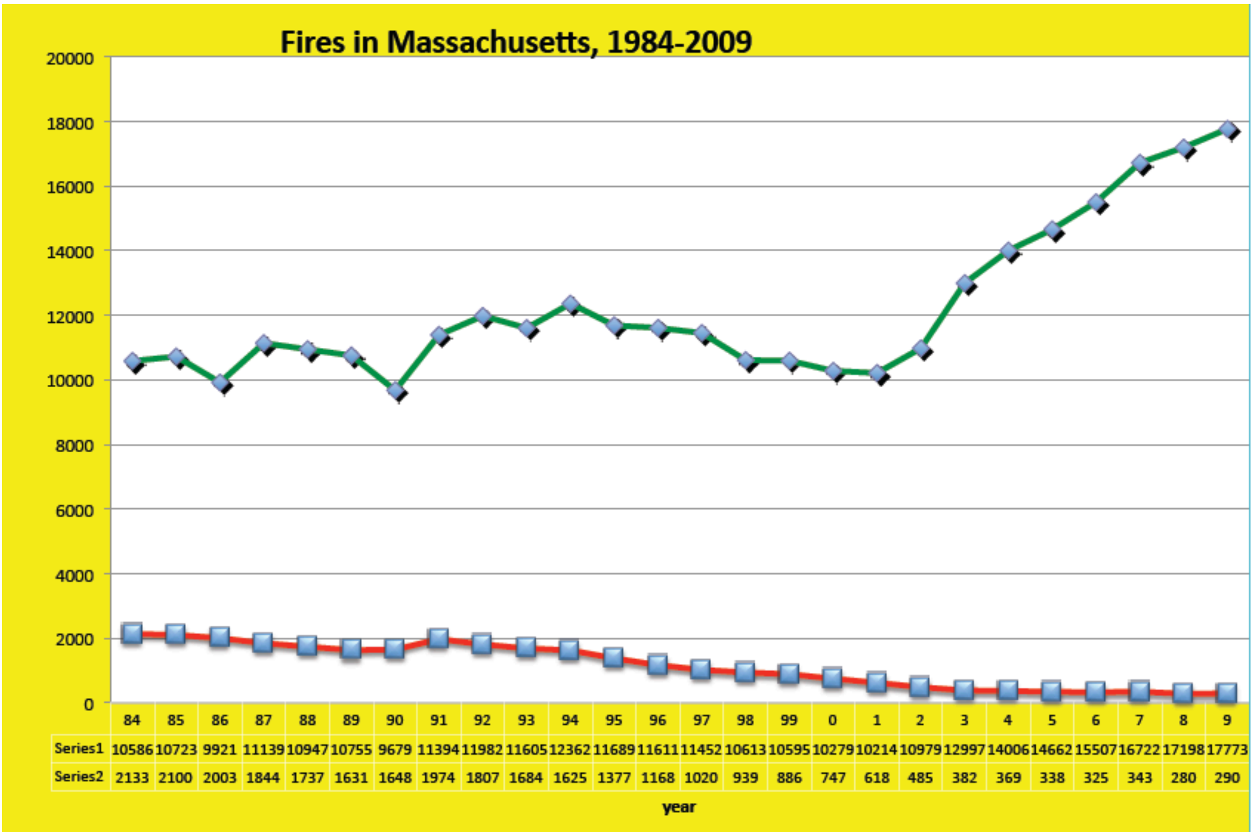


Figure 1. (top) A comparison of the number of fires versus the number of arsons in Texas over an eleven.-year period. (bottom) Percentage of fires determined to be arson, by year.



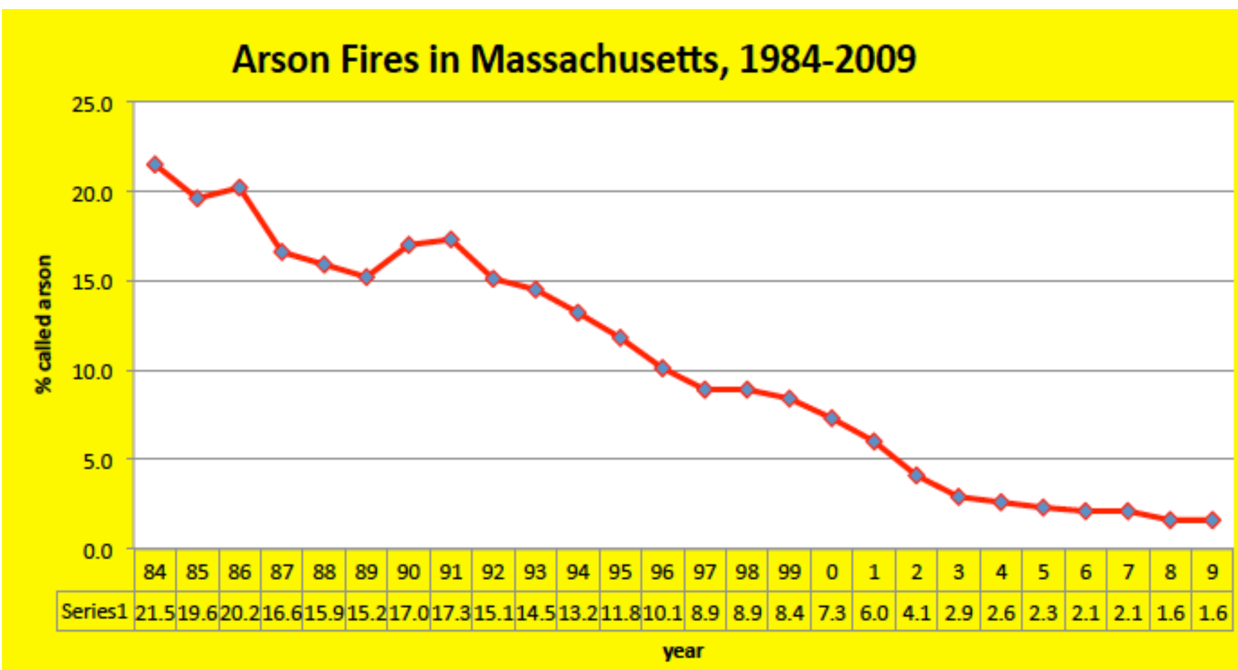


Figure 2. (top) A comparison of the number of fires versus the number of arsons in Massachusetts over a twenty-five-year period. (bottom) Percentage of fires determined to be arson, by year.

from Texas, Jack Nicas, a reporter for the *Boston Globe* performed the same exercise in Massachusetts, with even more startling results. Between 1984 and 2008, the percentage of fires determined to be arson in Massachusetts dropped from over 20% to less than 2%, despite a net increase in the total number of fires. Nationwide, from 1999 to 2008, the NFPA reports a drop from around 15% to around 6% in the percentage of fires determined to be arson.

Statistics can be slippery, but the clear trend in all of these studies is downward. Mann attributed all of the change to fire investigators making fewer mistakes, while Massachusetts State Fire Marshal Stephen D. Coan attributed the decrease in arsons to more fire education, visibility of law enforcement, and successful prosecutions. Coan said the data simply shows a job well done. (Jack Nicas, "Another Arson Conviction Challenged," *Boston Globe*, September 8, 2010.) Both views seem a little extreme. One other factor to take into account is the changing terminology of fire and arson investigation. The National Fire Incident Reporting System (NFIRS) documents formerly included a category called "incendiary or suspicious." The term "suspicious" has now been dropped at the urging of the NFPA Technical Committee on Fire Investigations. So fires are less likely to be reported as incendiary, even if a fire investigator happens to harbor some suspicions.

But surely, at least some of the downward trend can be accounted for by fire investigators taking a more cautious approach, and being more cognizant of the consequences of their determinations. This caution is probably **not** the result of old-school fire investigators changing their ways. NFPA 921 has now been a fact of life for 20 years, a time period during which many poorly trained investigators have had the opportunity to retire, and new fire investigators have always been aware of the need for more caution. As the great scientist Max Planck put it, "Science advances one funeral at a time." New ideas tend to spend a fair amount of time in the "heresy box," and new ideas in fire investigation are no exception. When it was first posited in the mid-1980s that full room involvement could be responsible for irregular patterns on a floor, many fire investigators derided that idea as "the flashover defense."

Flashover is a transition that takes place in a structure fire. It is a phenomenon that most people are not familiar with, because it does not happen with outdoor fires.

The concept that “heat rises” is familiar to everybody, but indoors, the heat only rises until it reaches the ceiling. When the fire undergoes flashover, it is said to make the transition from “a fire in a room” to “a room on fire.” Prior to flashover, a fire grows by involving more fuel. Once flashover occurs, all of the fuel that can be involved is already involved, and the fire can only grow where it has sufficient ventilation. The fire is said to have made the transition from a “fuel-controlled” fire to a “ventilation-controlled” fire.

It was only when fire investigators began allowing their weekend seminar training fires to continue for a few minutes after flashover that they began to realize what the fire protection engineers were saying was correct. **The rules for interpreting fire damage change once the fire becomes fully involved.** There is still a small but significant cadre of fire investigators fighting a rear guard action who refuse to accept this fact, but acceptance is coming. The best training that fire investigators receive no longer focuses on teaching them to “recognize arson,” but on teaching them how to understand fire patterns, particularly the effects of ventilation on post-flashover fires.

THE NEW SCIENCE OF POST-FLASHOVER BURNING

2005 marked another major turning point in our understanding of fire behavior, as well as our understanding of the reliability of fire origin determinations. A group of certified fire investigators from the Bureau of Alcohol Tobacco and Firearms (ATF) consisting of Special Agents Steven Carman, Daniel Heenan, Michael Marquardt, and Fire Protection Engineer Gerald Haynes designed an experiment that mirrored similar experiments that had been conducted (but not documented) at the Federal Law Enforcement Training Center in Glynnco, GA.

These investigators set up two rooms, simple 12 by 14 foot bedrooms, set each of them on fire, and allowed them to burn for about two minutes after they flashed over. They then asked 53 participants in a Las Vegas IAAI-sponsored fire investigation seminar to walk through the burned compartments and to write down the **quadrant** in which they believed the fire had originated. In the first compartment, three participants identified the correct quadrant. When the exercise was repeated on the second compartment, three different participants identified the correct quadrant.

These results caused much consternation, particularly as Special Agent Carman began presenting the results to groups of investigators. His bottom line was “The “old-days” of locating the point of origin of a post-flashover fire by relying on the "lowest burn and deepest char" are **over**! Yet the "lowest and deepest char" is still the most often cited data used to support a fire investigator's origin determination. Although it may seem reasonable that the charring will be greatest where the fire burned the longest, that is simply not true for fully involved fires, and such determinations are ripe for a reliability challenge.

When word of the ATF experiments got out into the fire investigation community, people immediately began to examine the data more closely, because an error rate over 90% was simply unimaginable! In fact, the poor results should not have surprised anyone. Agent Carman reports that in the undocumented tests at Glynnco, the success rate was 8 to 10%. (Steve Carman, "Improving the Understanding of Post-Flashover Fire Behavior," Proceedings of the 3rd International Symposium on Fire Investigations Science and Technology (ISFI). Available at http://www.carmanfireinvestigations.com.) Certainly, the participants in the Las Vegas tests were not allowed to interview witnesses, nor were they allowed to shovel any of the debris or perform any of the other activities besides visual observation that typically take place at a fire scene. The qualifications of some of the participants were found to be less than stellar, and some people were taking part in the experiment just to familiarize themselves with fire investigative procedures.

No matter how many explanations for the low success rate were offered, however, there was no way to increase the number of correct origin determinations beyond three. Reducing the denominator (the total number of "experienced" participants) might raise the percentage of correct answers to 10% or even 20%, but it is important to remember that 25% is the percentage of correct answers that would be expected if the quadrant containing origin were selected at random. The fire patterns definitely misled most of the investigators, whose professed expertise was "reading fire patterns."

In an attempt to understand what was going on, Agent Carman and his collaborators at ATF re-created the test fires at the ATF Fire Research Laboratory in Ammendale, MD, and modeled the results using computational fluid dynamics (See the sidebar on Computer Fire Modeling). What came out of these studies was a better, but certainly not complete, understanding of the effects of ventilation in post-flashover fires. The results of these studies have now been incorporated into two very well produced training modules, available at no cost at www.CFITrainer.net. Even non-scientists can understand these modules.

The principal problem with determining the wrong origin is that **the ignition source will not be found there.** Finding an origin without an accidental ignition source will lead investigators who don't understand the physics to conclude that somebody must have placed some fuel at that origin and ignited it with an open flame. If there is an irregular burn pattern on the carpet in that area, even in the absence of a positive laboratory report, the investigator will almost certainly conclude that the fire was intentionally set using a flammable liquid. Many investigators have made errors using this kind of "negative corpus" determination. Finding the correct origin the key to a correct fire cause determination, and is the most difficult part of the investigation of a fully involved compartment fire.

In 2007, ATF agents refined and repeated the Las Vegas experiment, this time in Oklahoma City. They set up three burn cells, with identical fuel and identical ventilation, but different points of origin. The cells were allowed to burn for 30 seconds beyond flashover, 70 seconds beyond flashover, and 180 seconds beyond flashover. To put these times in context, the best fire departments in big cities **might** have a three-minute response time. If they are not called until someone sees the fire venting out the window (a sign of flashover) the chances of them extinguishing the fire with less than three minutes of post-flashover burning are practically zero. The results of the Oklahoma City experiment validated the data from Las Vegas obtained two years earlier. Further, it became clear that the longer the fire was allowed to burn after flashover, the less likely the fire investigators were to correctly identify the quadrant of origin. The results of the Oklahoma City experiment are shown in Table 1.

Post-flashover burning time	# of responses	# Correct	% Correct
30 seconds	70	59	84
70 seconds	64	44	69
180 seconds	53	13	25

Table 1. Results of 3 burn cell tests conducted to measure fire investigators' ability to determine the correct quadrant of origin

There were, apparently, six investigators who ruled the origin "undetermined" based on the fact that they did not turn in a response for the 70-second post-flashover fire, and 17 investigators who declined to select a quadrant of origin when the fire had burned for 3 minutes beyond flashover.

Of those 53 investigators who did respond, only twenty-five percent (25%) got the quadrant of origin correct. While this is a better result than the 6% obtained in Las Vegas, it was **no better than would be expected if the investigators had chosen the quadrant of origin at random**. Further, there are those who would argue that 69% correct or even 84% correct are low numbers, when one is using those determinations to either send people to prison, or to deny them coverage under their homeowner's policy.

What these results show is a fundamental unreliability of many fire origin determinations. What these results also show is that fire investigators **and the people who use them as experts** need to be prepared to accept the reality that sometimes the best answer that can be obtained is "undetermined," if either an accidental or an incendiary call is not supported by conclusive evidence.

SIDEBAR

ACCELERANT DETECTING CANINES

In 1982, the Bureau of Alcohol, Tobacco and Firearms (ATF) pioneered a program to bring trained canines into fire scenes to aid in the detection of ignitable liquid residues. These "accelerant detection canines" (ADCs) are a valuable tool to assist fire investigators in selecting samples that have a high probability of testing positive when submitted to a laboratory. Unfortunately, this tool has been misused over the years, and despite the scientific community's disparagement, the use of dogs in the courtroom continues. See for example, Judge Gertner's 2010 order to vacate conviction in the case of *United States vs. James Hebshie* (Criminal No. 02cr10185-NG)

In 1994, a group of scientists (including this author) on the International Association of Arson Investigators Forensic Science Committee developed a position paper that stated essentially that an ADC alert for might be acceptable in the context of finding probable cause to look further, but that no jury should ever hear about an unconfirmed canine alert. This position was ratified by the National Fire Protection Association (NFPA) in 1996, when an emergency amendment was added to NFPA 921, so that courts could be advised that unconfirmed canine alerts did not constitute valid science. This seemed to reduce the use of unconfirmed canine alerts in arson cases, at least for a while. The Georgia Supreme Court in 1996 overturned Nancy Grace's last conviction because she had used 12 unconfirmed canine alerts as evidence in the case against Weldon Wayne Carr. (*State of Georgia v. Weldon Wayne Carr*, 482 S.E. 2d 314 (1997).)

When the NFPA addressed the subject in 1996, the Technical Committee on Fire Investigations wrote, " The committee, as specially trained members of the scientific, engineering and fire investigative community, know that evidence and testimony relied upon by our nation's courts have been empirically proven to be false. In essence, a fraud is being perpetuated upon the judicial system." The statement is as true today as it was then. But today, the lessons of the 90s seem to have been lost on some prosecutors and fire investigators who are once again trying to persuade juries that dogs are more sensitive than laboratories, and that unconfirmed alerts by a dog that cannot be cross-examined, constitute relevant evidence. It is neither relevant nor reliable, but some trial court judges let these unconfirmed alerts into evidence anyway.

Consider the case of drug-detecting and explosive-detecting canines. If a canine trained to detect drugs alerts on a suspect's briefcase, but no drugs are found, no charges for possession of drugs are brought. If a canine trained to alert to explosives alerts to a traveler's suitcase, and no bomb is found, no charges for possession of explosives are brought. The only difference between accelerant detecting canines and drug- or explosive-detecting canines is that unconfirmed ADC alerts are sometimes allowed as evidence. Some fire investigators hold to the belief that "Dog said it. I believe it. That settles it."

Laboratories today are capable of detecting 0.1 µL (1/500 of a drop!) of ignitable liquid residue and a gallon of fire debris without breaking a sweat. If the laboratory is unable to find any ignitable liquid residue, having the dog handler testify "There really was something there but the laboratory missed it," has the potential for setting up a gross miscarriage of justice. Such unconfirmed alerts should not be put forward by prosecutors, and if they are, defense counsel should object most strenuously. And the Judge should not allow such witchcraft to be presented to the jury.

SIDEBAR

COMPUTER FIRE MODELS

There are many processes taking place simultaneously in a structure fire. Energy is being released by the burning fuel and transferred to the surrounding fluids (air and smoke) and solids in the environment. The temperature of the room is increasing. A fire plume is carrying the products of combustion upward and a hot gas layer forms and then grows deeper. The gas layer radiates energy onto other fuel packages in the room and conducts energy into the walls and ceiling. Chemical bonds are being broken and new ones are being formed. The concentrations of gaseous species in the room are changing as oxygen is consumed, and carbon dioxide, carbon monoxide, water, and other combustion products are generated.

A model is an attempt to use quantitative information to mathematically describe how some or all of these processes will change over time under specific conditions. The algebraic equations used to compute flame are simple examples of fire modeling, a relatively new discipline based on the idea that fire might be studied numerically. The algebraic models are known as “hand” calculations or correlations. The more complex models use multiple differential equations (calculus), which must all be solved simultaneously but using numerical methods. This requires a computer, as well as the ability to describe the structure and its contents on a three-dimensional grid.

Fire models were not initially designed to be used in fire investigations. They have been developed by fire protection engineers, largely as a means to avoid actual fire testing, or to leverage data collected in fire tests to avoid additional testing. Some fire protection engineers will state (not entirely in jest) that in the 21st century, their whole reason for existence is to eliminate the fire resistance test. Fire models are the means to that end. Of course, live fire tests are necessary to validate any fire model.

The fundamental equations describing heat transfer, fluid dynamics, and combustion have been known for over a century but the complexity involved in simultaneously solving for all the important variables, especially in an uncontrolled fire, was too daunting for even the most mathematically savvy engineers. There were simply too many things happening at once. The number of equations is not only large due to multiple phenomena occurring simultaneously, but also because the associated variables are highly coupled. A change in one parameter, such as the concentration of CO_2, causes several other parameters to change.

Other impediments to mathematical modeling include the facts that fire scenarios can be varied almost infinitely, and the fuels under consideration were not designed to be fuels. They were designed to be chairs, beds, and building materials.

It was not until the beginning of the information age that there was sufficient computing power for the development of models that could be applied to fires, but only simple models, zone models that divided a compartment into two layers, could be handled. However, it was a start. Researchers knew that the best understanding of a fire would come when the compartment could be divided into smaller and smaller cells, ranging from a cubic foot down to a cubic inch. These models, known as field models, provide much more information, but require more inputs and take much more computing power to run. Even as recently as the late 1980s, the amount of computing power required was beyond the reach of all but a few researchers lucky enough to have very fast computers with very big memories. In the mid-1990s, it was not uncommon for a computer to require two months of number crunching to test a single scenario using computational fluid dynamics. In fact, such long runs are common today because the larger, faster computers are being asked to do more calculations.

During the 1940s and 1950s, government offices in the United States, United Kingdom, and Japan were set up to study the quantitative aspects of fire. The First International Symposium on Fire Research, sponsored by the National Academy of Sciences, was held in Washington, D.C., in November of 1959. Initially, burning liquid pool fires were studied because of their simplicity; but by the mid-1960s, there was a consensus in the scientific community that it might be possible to model more complex fire phenomena. In 1976, James Quintiere presented a paper entitled "Growth of Fires in Building Compartments" at an ASTM symposium. The first published fire model, by the Illinois Institute of Technology Research Institute (IITRI) in the mid-1970s, was influenced by Quintiere's approach and demonstrated the potential of this tool for use in fire protection engineering design. Other models soon followed, and as each was published, the next generation merged the equations and algorithms from previous models, so that more and more aspects of fire development could be taken into account. In 1986, Harold "Bud" Nelson of NBS (now NIST) merged several hand equations with an egress time model and a sprinkler response model to produce FIREFORM, which he later expanded into FIRE SIMULATOR and FPETOOL, which was released in 1990. British and Australian teams produced similar program "suites" of fire engineering calculations. Multi-room models were first seen in the early 1980s. A model called FAST (Fire And Smoke Transport) was released by the Center for Fire Research at NBS in 1985. It was merged with a faster numerical problem solver and became CFAST (Consolidated Compartment Fire and Smoke Transport model), which is still in use today. CFAST is a *zone model* that divides each compartment into only two zones — an upper and a lower zone — connected by the fire plume.

Field models, which were developed in the United States and elsewhere, utilized computational fluid dynamics (CFD) to model the behavior of a fire in many individual cells. These models solve multiple simultaneous differential equations to balance mass, energy, and momentum in all of these thousands or millions of cells. NIST's current model is FDS (Fire Dynamics Simulator). Perhaps one of NIST's most useful achievements in the field of modeling is its development of SMOKEVIEW, a program that transforms the output of FDS into a three-dimensional view of the fire in progress, which can be tuned to examine smoke, particles, gas temperatures, boundary temperatures, and chemical species. Numerous examples of the output of the SMOKEVIEW program can be viewed at the NIST website.

Although CFD models such as FDS examine a fire in much finer detail than zone models, there are trade-offs. Once the data describing the compartment or structure has been input, zone models can be run in a few minutes of processor time, while a CFD model may take days, weeks, or months. There is a place for both kinds of models. Multiple scenarios can be run using a zone model, to select one or two scenarios for CFD modeling.

Because the NIST models have been largely developed at taxpayer expense, the NIST website (fire.nist.gov) allows anyone to download any of their models and user manuals at no charge.

NIST mathematicians and fire protection engineers have used their models to assist fire investigations, including most of the major events that have occurred in the past decade. These include the Station nightclub fire (a Warwick, RI nightclub where 100 people died), the Cook County Administration Building fire, and the World Trade Center attacks. Models can be useful in developing or testing hypotheses, but care must be used in their interpretation. As with any computer simulation, the GIGO rule applies. Models require the use of assumptions and approximations. More complex models make fewer simplifications but require more data input. If an incorrect assumption is used or a parameter is incorrect, an incorrect answer is the likely result.

A model does not take the post-fire artifacts and run the fire in reverse to find the origin. The proper use of the model is to propose an ignition scenario and then run the model forward in time to see if the model accurately predicts the outcome. One of the best uses of a fire model is to test the effects of changing a significant parameter by asking "what-if" questions. What if we had sprinklers in place? What would have happened if: the stairwell door had not been propped open, or the smoke detector had batteries in it, or if the interior finish had been fire resistant drywall instead of plywood paneling?

Answers that a fire protection engineer might consider to be “in relatively good agreement” may be too imprecise to address certain questions in the context of a fire origin and cause investigation. The uncertainty associated with the predictive abilities of models is their principal drawback. While the measurements taken in actual fire tests can have uncertainties of up to 30%, real tests involving real fires still have more credibility than computer models in some quarters. Confronted with a computer model that predicts a fire resistance of 2 hr for an architectural assembly, a fire official might demand proof that the model is valid. Confronted with a hypothesis that a fire began or spread in a particular way based on a model, a party to fire litigation might ask for similar proof.

If an investigator were to conduct five identical fire experiments, the value for any given variable (temperature, CO concentration, smoke density, etc.) at a particular point in space and time would vary from test to test; and if enough tests were run (a very expensive proposition), the “error bars” for each value could be determined, assuming accurate measurement capabilities. If the investigator puts the same data into a computer model, however, only one value comes out. Both CFAST and FDS come with the following disclaimer in their user manuals:

> The software package is a computer model that may or may not have predictive capability when applied to a specific set of factual circumstances. Lack of accurate predictions by the model could lead to erroneous conclusions with regard to fire safety. All results should be evaluated by an informed user.

The definitive guidance for selecting and using models to answer questions about a fire can be found in the Society of Fire Protection Engineers (SFPE) Engineering Guide, “Guidelines for Substantiating a Fire Model for a Given Application.”

What does the availability of models mean for the fire investigator? That depends entirely on the nature of the question that the fire investigator asks. A model will not locate the origin of the fire, nor will it determine the cause. There has been a disturbing trend for fire investigators to use hand models or spreadsheet calculators such as CFI calculator in inappropriate ways. Models simply do not have the ability to resolve many issues that concern the fire investigator.

When fire protection engineers are designing a sprinkler system, they have the option of using a model to help them, but they do not base their fire safety engineering decisions entirely on the output of the model. It is a relatively simple matter to over engineer the system, so that if the model states that 10 sprinkler heads will do the job, 15 might be put into the final design.

Some fire investigators estimate the heat release rate required to bring a room to flashover using models, then they estimate the heat release rate of a proposed single fuel package, and if that package is "insufficient," these investigators will declare that there must have been two or more points of origin. If there is insufficient physical evidence on the fire scene to reach a conclusion as to the origin and cause of the fire independent of the model, relying on the model to answer these questions is invalid and irresponsible. It almost goes without saying that fire determinations based on modeling should be challenged. The model was simply not designed for that application. Examples of "successful" modeling often include a comparison of the output of the model with a videotape of the actual fire. The Station nightclub is a good example of such a success story. The only reason that the model can so successfully mimic the videotape is that the videotape existed. The first time the model was run, it predicted flashover in less than six seconds. Repeated iterations of data entry were required to get the model to agree with the videotape. If there is insufficient evidence at the fire scene to even formulate a testable hypothesis, the model output amounts to nothing more than computerized speculation. People are impressed with numbers, but the mere circumstance that data can be quantified and manipulated is no guarantee that the results will portray anything real.

Despite the uncertainties involved, modeling as a tool to test hypotheses is becoming more common in fire investigation. Carville reported using a CFD model named JASMINE (a BRE/FRS program) to test five different origin scenarios in a building where the damage prevented any determination of even the room of origin. The model was run to see which scenario best matched witness observations, and of the five scenarios proposed, the model clearly favored one. Such "investigations" represent an interesting trend but one that requires constant vigilance. In the case of Carvel's fire, the model and the witness observations were all he had to work with. One hopes that the results were not used in litigation.

An interesting comparison of model predictions versus real world fire behavior was conducted in 2006 by Rein, Torero, others. In this exercise, conducted at Dalmarnock (Glasgow) Scotland, Ten teams of modelers, eight using FDS4 and two using the 2000 edition of CFAST, were asked to predict fire behavior in a typical apartment in a high-rise building. The modeling teams were provided with more information than is typically available to a modeler investigating a real world (non-experimental) fire, but unlike many other comparisons of model "predictions" versus actual fires, the modeling teams were not given much of the experimental data. They were asked to predict time to flashover and upper layer gas temperature, among other parameters. The predictions varied widely from each other and they varied widely from the experimental results. The authors of the study reported "the accuracy to predict fire growth (i.e. evolution of the heat released rate) is, in general, poor." (Guillermo Rein, Jose Torero, et al. Round-Robin Study of *a priori* Modeling Predictions of The Dalmarnock Fire Test One, Fire Safety Journal 44 (4), pp. 590-602, 2009.available at www.era.lib.ed.ac.uk/handle/1842/1152).The authors stated that with a lot of labor, a model's output could be made to fit the post-fire artifacts when those were already known to the modelers (*a posteriori*), but the track record for actual prediction was not so good. The study's authors cite Sir Winston Churchill who said, ''I always avoid prophesying beforehand because it is much better to prophesy after the event has already taken place''

While modeling is an interesting tool, it is, in this author's view, "not ready for prime time" concerning fire investigation, and not sufficiently reliable to be admitted into evidence. One New York Court has already ruled this to be the case. Here are a few points made by Judge Phelan:

- "that computer fire modeling, when used to determine the cause of a fire, would be novel for that purpose and is not generally accepted in the fire investigative community.
- "the expert has not demonstrated its general acceptance in fire investigation."
- "Although defendant's expert may support a case for the acceptance of computer fire modeling in the regulatory/design community, it does not support a conclusion that it is generally accepted in the fire investigative community." (*Santos vs. State Farm* 000790/07 2010 N.Y. Misc. LEXIS 2803; 2010 NY Slip Op 20255)

One can use models to make conservative engineering decisions, but using it to "predict" the behavior of a particular fire is likely to lead to error. Until models can be shown to accurately describe what is going to happen without the modeler being provided with a videotape of the fire from its ignition until its extinguishment, the output of any model should be viewed with extreme skepticism, and challenged accordingly. If the classification of the fire cannot stand on its own without the use of a model, then the classification should remain undetermined.

WHAT THIS MEANS FOR THE JUSTICE SYSTEM

Fire investigation is a complex endeavor that requires practitioners to make numerous sophisticated decisions involving chemistry and physics. It would be wonderful if all fire investigators were up to the task, but our society has elected not to reward fire investigators for obtaining the fundamental knowledge required to do their jobs. Salaries for public sector investigators are often insufficient to attract college graduates. Most public-sector investigators get their training "on-the-job" where the belief systems of their seniors are passed down. Certainly it is possible for individuals with no chemistry or physics beyond high school to apply themselves and learn the basic science, and keep up with developments in the field. But funds for such training are limited.

The reality is that the fire investigation profession contains within it a large number of persons who don't know what they're doing, and are blissfully unaware of the work of Agent Carman and his colleagues and others before them, who have been trying for years to get across the point **that post-flashover patterns must be interpreted differently** from unconfined fire patterns. The only word for such individuals is "hacks." Hacks work cheap, and they work quickly, but when they make an arson determination, it will often fail to withstand even mild scrutiny.

There are methods available for identifying who is a hack and who is qualified to do this important work. One hopes that this vetting of the fire expert is accomplished by the prosecutor prior to bringing a case, and by defense counsel prior to hiring an expert. It has been held in the 6th Circuit that in a fire case where the cause is contested, the assistance of a **competent** expert is a component of effective assistance of counsel. (Kenneth T. Richey v. Betty Mitchell, Warden). There now exists a standard for professional qualifications for fire investigators, which applies equally to public and private sector investigators. NFPA 1033, *Standard for Professional Qualifications for Fire Investigator*, 2009 edition, contains a list of subjects in which a fire investigator is supposed to have up-to-date knowledge. Here are the words of that standard:

> **1.3.7*** The fire investigator **shall** remain current with investigation methodology, fire protection technology, and code requirements by attending workshops and seminars and/or through professional publications and journals.

1.3.8* The investigator **shall** have and maintain at a **minimum** an up-to-date basic knowledge of the following topics beyond the high school level at a post-secondary education level:

(1) Fire science
(2) Fire chemistry
(3) Thermodynamics
(4) Thermometry
(5) Fire dynamics
(6) Explosion dynamics
(7) Computer fire modeling
(8) Fire investigation
(9) Fire analysis
(10) Fire investigation methodology
(11) Fire investigation technology
(12) Hazardous materials
(13) Failure analysis and analytical tools (**emphasis** added)

It is quite a simple matter to put together a small "quiz" to see if a fire investigator knows the definition of "thermodynamics" or "fire science," or if he or she knows enough fire chemistry to describe the combustion of hydrogen. An investigator who has failed to maintain "an up-to-date basic knowledge" of these topics is someone who does not need to be investigating fires. It is embarrassing when your investigator "eliminates" a gas fire, but does not know that natural gas is mostly methane or that the chemical formula for methane is CH_4.

Reading an investigator's report is another way to tell if an investigator is qualified. Incendiary fire classifications based on fires that burned "hotter than normal," or based on concrete spalling or a melted aluminum threshold, or based on an unconfirmed canine alert, or based on any of the mythology that has been discredited by NFPA 921 are likely to be incorrect. Basing a prosecution on such a report is likely to set the stage for a miscarriage of justice.

Preventing and punishing arson is an important function, but it is one that is not as simple as it was in the past. New knowledge about fire behavior and particularly about the difficulty in correctly determining even **where** a fire that burned beyond flashover started has placed new burdens on those charged with investigating fires. Agencies that accept these responsibilities will have a credible deterrent effect on arson. As long as there are those who provide support to the hacks, however, horror stories about wrongful prosecutions and convictions will undermine the public's confidence in the ability of the justice system to respond appropriately to fire losses.

ABOUT THE AUTHOR

John Lentini has been deeply involved in most of the important developments in fire investigation in the past 25 years. He began his career at the Georgia Bureau of Investigation Crime Laboratory in 1974. There he learned forensic science in general and fire debris analysis in particular, and received an introduction to fire scene investigation. He went into private practice in 1977 and spent the next fifteen years working 100 to 150 fire scenes per year, mostly for insurance companies that had doubts about the legitimacy of their insureds' fire losses. At the same time, he managed a fire debris analysis laboratory with a nationwide clientele.

Mr. Lentini has been a certified fire investigator since certification first became available, and was among the first group of individuals certified by the American Board of Criminalistics in fire debris analysis. He is one of the few fire investigators in the world who holds certifications for both laboratory and fire scene work.

He has been a contributor to the development of NFPA 921, *Guide for Fire and Explosion Investigations*, and has been a member of the National Fire Protection Association's Technical Committee on Fire Investigations since 1996.

He is the author of more than 25 technical publications. His study of the Oakland Hills fire in 1991 resulted in a rethinking of much of the conventional wisdom in fire investigation, and his laboratory work has resulted in research papers that are standard works in the field.

Mr. Lentini has personally conducted more than 2,000 fire scene inspections, and has been accepted as an expert witness on more than 200 occasions. He is a frequent invited speaker on the subject of the standard of care in fire investigation and laboratory analysis of fire debris, as well as on the progress of standardization in the forensic sciences. His book, *Scientific Protocols for Fire Investigation*, (CRC Press, 2006) is available at Amazon.com.

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